The Mercury MESSENGER

Issue 4 | The newsletter concerned with exploration of the planet Mercury | August 1990

MISSION TO MERCURY: Report of NASA Working Groups

Science and Engineering Reports

A NASA Science Working Team (SWT) (chaired by Professor J. W. Belcher of MIT) and a JPL engineering study team (chaired by Dr. Chen-Wan Yen of JPL), formed under the auspices of the Space Physics and Planetary Exploration Divisions of NASA Headquarters, have just released their reports on a Mercury Orbiter mission. The Space Physics Division in particular has long been an enthusiastic supporter of a mission to Mercury, and NASA was willing to take the first step toward a possible mission by forming these study teams. The work was carried out by over 40 scientists and engineers from a range of disciplines, including magnetospheric and planetary physics, solar physics, planetology, and spacecraft and mission design. The teams responded enthusiastically to the request to consider such a mission.

The Mariner 10 flyby mission to Mercury in 1974 and 1975 provided results that led the space physics community to be especially interested in that planet: Mercury (unlike Venus, Mars, and the Moon) was found to have an intrinsic magnetic field apparently resulting from a fluid outer core like the Earth's. In addition, Mercury was found to have major tectonic features, such as a scarp system, indicative of an early active history quite different from the Moon's and perhaps more like the Earth's. Earth-like magnetic substorms were also observed.

Difficulties in trajectory and thermal design kept a Mercury mission from being given serious consideration prior to the late 1980s. At that time, breakthroughs in both areas led to the awareness that a moderate-cost mission to Mercury could yield major advances in our understanding of Mercury's surface and fields and particles environment. The space physics working groups proposed such a mission, which involves two spin-stabilized spacecraft (see Fig. 1) to be launched by a single Titan IV Centaur vehicle. The mission would have a 3- to 5.5-year gravity-assist trajectory, and a nominal one Earth-year duration mission at Mercury.

The SWT held three workshops in 1988 and 1989, and then produced a NASA Technical Memorandum (officially released on June 1, 1990) entitled *Mercury Orbiter: Report of the Science Working Team*. Spacecraft engineering and mission design studies were conducted simultaneously, and the resulting JPL report (D-7443, released May 29, 1990) was entitled *Mercury Dual Orbiter Mission and Flight System Definition*. The engineering study indicated that the proposed spin-stabilized spacecraft, carrying a payload of comprehensive particles and fields experiments and key planetology instruments, could survive and function in elliptical orbits without costly sun-shields and active cooling systems.

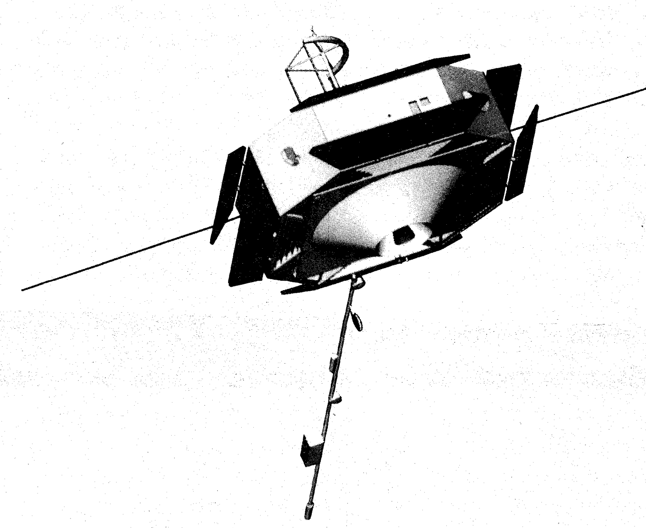

Fig. 1. Mercury Orbiter spacecraft in flight configuration.

Engineering Study Designs

The mission and spacecraft design studies carried out at JPL focused on providing a reasonable accommodation of the sometimes competing objectives of a wide range of scientific disciplines. In this process, space physics objectives were emphasized, along with engineering considerations associated with the particularly harsh thermal and radiation environment of Mercury, spacecraft system requirements, and cost constraints.

In response, the spacecraft design is based on a novel use of conventional technology, eliminating the need for high-risk technology development. The spacecraft (see Fig. 2 as well as the figure in Issue 3, *Mercury Messenger,* August 1989, for details) has an oblate "tuna can" shape that is well suited for spin stabilization. Its frame consists of graphite epoxy struts, aluminum plates, and aluminum honeycomb sheets covered with either aluminum or graphite epoxy face plates. Small bipropellant thrusters control spin rate and spin axis precession. These thrusters and the larger engine are used in the multiple ΔV maneuvers. Instrument sensors are located near the spacecraft perimeter and on booms, giving the instruments excellent field-of-view coverage and, in the latter case, reducing interference. Solar panels, articulated in cone angle with respect to the spin axis, are used for power and rechargeable batteries provide energy storage.

A central computer provides command, control, and telemetry processing for all the engineering subsystems, while specialized science data processing and telemetry packetization are carried out in the science instrument packages. Tape recorders store telemetry between downlink opportunities, and the high-rate X-band communications utilize a despun high-gain antenna that is a derivative of that used on the Helios spacecraft.

The propulsion subsystem structure is integrated with the electronics bus structure. The result is a compact design for the spacecraft central body that reduces mass, lowers height and center of mass in the launch vehicle (allowing two spacecraft to be stacked), and helps maintain a constant center of mass location (simplifying spacecraft dynamic control).

In flight, the spacecraft spin axis is held perpendicular to the sun direction. This has multiple benefits: The top and bottom surfaces of the spacecraft are sun-free, allowing them to be used for radiative cooling; incident solar flux is effectively distributed around the spacecraft perimeter, isothermalizing the spacecraft and minimizing peak temperatures; solar panel input and electrical power output control is simplified; and the necessary high-gain antenna tilt range is reduced.

The innovative flight trajectory scenarios involving multiple flybys of Venus and Mercury were designed by Dr. Chen-Wan Yen (see her article in Issue 1 of the *Mercury Messenger,* December 1987). Duration of the flight to Mercury varies, depending on the launch opportunity. The first candidate opportunity is in 1997, the next in 1999.

The mission scenario at Mercury consists of two spacecraft in elliptical orbits with periods as low as 12 hours. One spacecraft is continuously in a polar orbit with periapsis near the north pole. The other spacecraft progresses through a series of equatorial orbits with differing geometries, and eventually ends up in a 12-hour polar orbit with a nearly equatorial periapsis, as shown in Fig. 3. The second spacecraft is in the latter configuration for most of the mission.

During the mission, the top and bottom of the spacecraft are exposed to intense heat flux when the spacecraft is at low phase angle and low altitude over the mercurian surface. During these exposure periods, which are usually less than 45 minutes out of a 12-hour orbit, the solar panels are rotated to cover the spacecraft cooling radiators. Insulation on the backs of the panels in this orientation

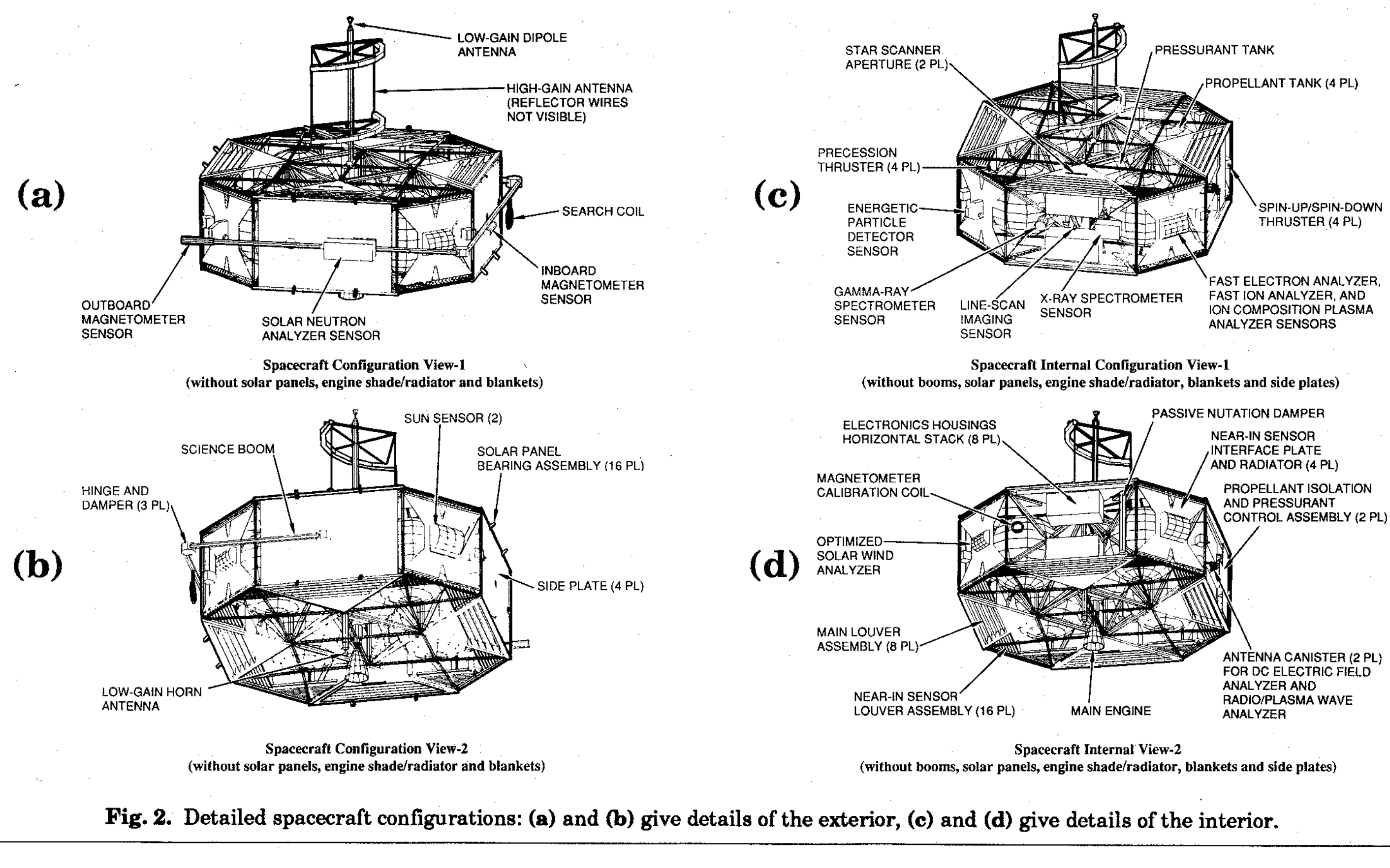

Fig. 2. Detailed spacecraft configurations: **(a)** and **(b)** give details of the exterior, **(c)** and **(d)** give details of the interior.

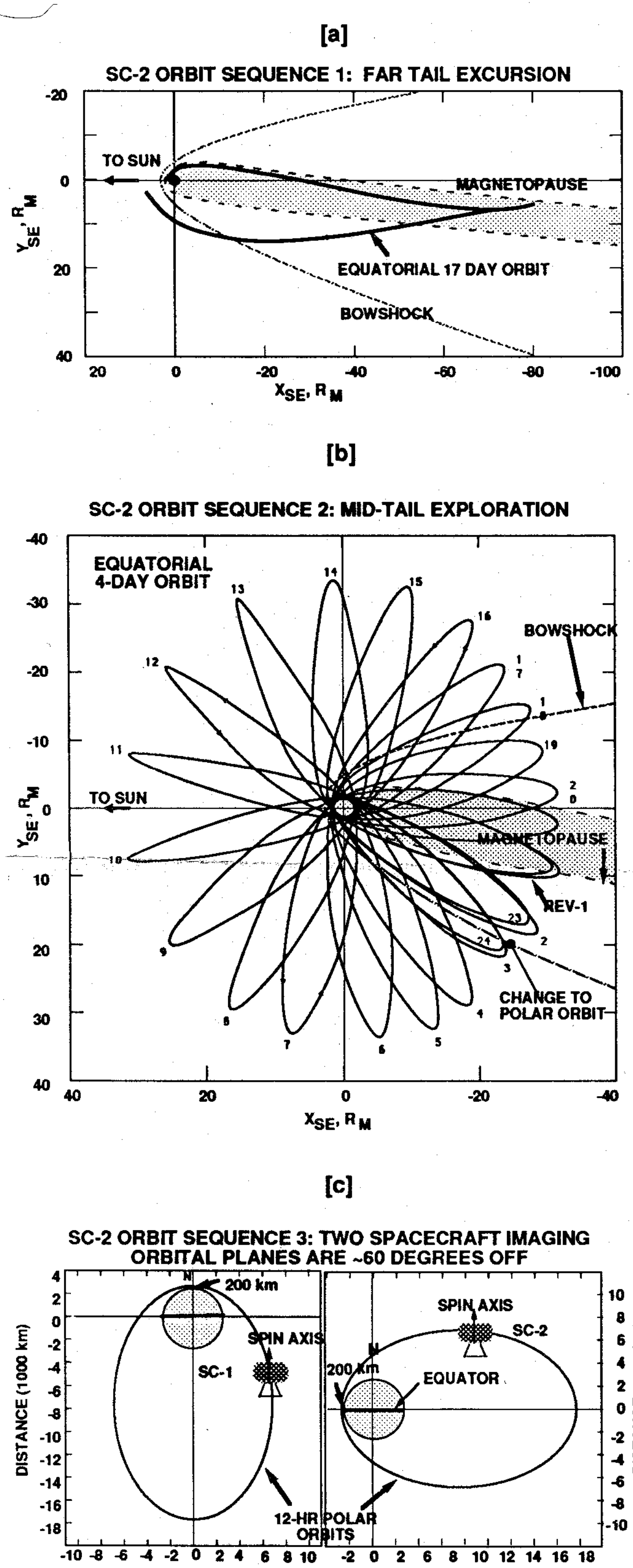

Fig. 3. Orbital configurations of spacecraft. Panels in order from **(a)** to **(c)** show the progression of Spacecraft 2 from various equatorial orbits into a 12-hour polar orbit with nearly equatorial periapsis. The configuration of Spacecraft 1 (a polar orbiter with nearly polar periapsis) is shown in **(c)**. Figures are drawn approximately to scale.

protects both the panels and the spacecraft interior from overheating. Additional protection is provided to thermally sensitive sensors via thermal blankets and sun shutters. When the spacecraft is in occultation, the panels can be rotated to a closed or partially closed position to prevent too much cooling of the panels and interior.

Science Goals and Recommendations

The SWT strongly endorsed the mission plan developed by the engineering study team. A single-launch-vehicle, dual-spacecraft baseline meets the fundamental magnetospheric science requirements. The coordinated orbit scenarios for the two spacecraft will provide unique particles and fields measurements unobtainable at other planets because of the constraints of orbital mechanics and the large dimensions of other magnetospheres relative to their planetary bodies.

The SWT identified a strawman payload that would meet the science objectives (see Table 1): magnetometer, electric field analyzer, ion composition analyzer, energetic particle detector, fast plasma analyzer, plasma wave analyzer, solar-wind plasma analyzer, solar neutron detector, line-scan imager, and gamma- and X-ray spectrometers. These proposed instruments have flown before and can fly again with few modifications.

The primary space physics objectives are to (1) map in three dimensions the magnetic structure and plasma environment of the magnetosphere, (2) study in detail the principal physical processes that occur during Hermean magnetospheric substorms with an emphasis on differences from Earth due to Mercury's lack of a highly conductive ionosphere, and (3) assess the role that interplanetary conditions have in determining the rate at which the Hermean magnetosphere draws energy from the solar wind and the manner in which it is later dissipated. The proximity of Mercury to the sun will be utilized to achieve fundamental solar and heliospheric physics objectives by

Table 1: STRAWMAN SCIENCE INSTRUMENTS

	SEN.[1] LO.	FOV (°X°)	RATE (KBPS)	POWER[2] (W)	MASS (KG)
DC ELECTRIC FIELD ANALYZER	WB	---------	.064-8.5	6.0	14.6
ENERGETIC PARTICLE DETECTOR	P	12X180 50X180	1-10	15.0	15.0
FAST ELECTRON ANALYZER	P	15X180	1-10	5.0	4.0
FAST ION ANALYZER	P	15X180	1-10	5.0	4.0
GAMMA/X-RAY SPECTROMETER	I	±10/±20	1.2-2.4	14.3	17.0
ION COMPOSITION PLASMA ANALYZER	P	15X180	1-10	12.0	10.0
LINE-SCAN IMAGING (AND TEC)	I	0.015X30	10	11.0	5.1
MAGNETOMETER	SB	---------	1-5	5.5	5.3
OPTIMIZED SOLAR WIND ANALYZER	P	45X180 70X180 160X180	0.4-4	10.0	10.0
RADIO/PLASMA WAVE ANALYZER	WB/SB	---------	032-10	6.5	4.6
SOLAR NEUTRON ANALYZER	SB	--------	0.5	10.0	10.0
				TOTAL	99.6

1. Sensor locations are: Internal, Perimeter, Science Boom, Wire Boom.
2. Loads are shown for the normal operating mode.

measuring neutrons and charged particles emanating from flare regions. In addition, the orbiter will be use to investigate heliospheric structure and dynamics between 1.0 and 0.3 AU.

The primary planetology science objectives for the orbiter are to (1) complete the global surface mapping initiated by Mariner 10, with more than 60% of the surface to be mapped at resolutions better than 250 m, (2) obtain Fe, Th, K, Ti, Al, Mg, and Si concentrations for the surface, (3) measure the intrinsic magnetic field in sufficient detail to allow for the detection of magnetic anomalies, and (4) map Mercury's gravitational field and associated anomalies.

In conjunction with the Earth-orbiting ISTP and CLUSTER missions of the 1990s, the Mercury Orbiter provides essential data for the formulation of the next generation of theories and models for the study of terrestrial-type magnetospheric structure and dynamics. The proposed mission will also return measurements critical for the understanding of not just the surface history and internal structure of Mercury, but the formation and chemical differentiation of the solar system as a whole.

Thus, the efforts of the Mercury Orbiter working groups have increased the interest and support for a Mercury mission within NASA. The Space Physics Division has given high priority to a Mercury Orbiter mission as a future candidate for a new start.

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Future Issues

In our next issue, we will discuss experiments involving observations of Mercury that test theories of gravitation and general relativity; these experiments were not considered in the reports of the working groups described above due to limitations in the scope of the study. We hope to bring you an issue describing the latest results on Mercury's atmosphere in a future issue. If you would like to contribute or suggest a topic for a future issue, please contact the editor or one of the co-editors. Please send materials or requests to the editor at the following *new* address: Pamela Clark, Albright College, Chemistry Department, P.O. Box 15234, Reading, PA 19612.

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